LITERATURE REVIEW ON SEISMIC RESPONSE ON UNDERGROUND STRUCTURE

[1]Shalini A. Thawrani, [2]Dr. Valsson Varghese

[1]M.tech Student (Structural Engineering), [2] Professor
Department of Civil Engineering K D K College Of Engineering, Nagpur, Maharashtra, India

***Abstract*— Infrastructure requirements in urban areas make mandatory construction of underground structure which serve as space for car parking and housing utilities of various kinds. Demand for underground space has increased which has triggered several levels of basement. Earthquake-resistant design of earth retaining structures like foundations retaining walls and earth dams are very important to minimize the devastating effect of earthquake menace. This paper reviews the effect of earthquake forces on underground structure. Since underground reinforced concrete structures interact with the surrounding soil, the behavior of the interfacial zone between the structure and the surrounding medium of the underground structure should be considered for accurate seismic analysis.**

Keywords: **underground structure, Earthquake-resistant design, surrounding soil, seismic analysis.**

I. INTRODUCTION

UNDERGROUND BUILDING CONCEPTS

A wide variety of approaches exists in the concept of underground structures. A building can be erected on the original surface of the ground i.e. at grade and then be covered by earth to shelter the building partially or completely or the building is constructed in a completely excavated site i.e. below grade. In between there are several different other types of underground building concepts as shown in **Figure 1**.

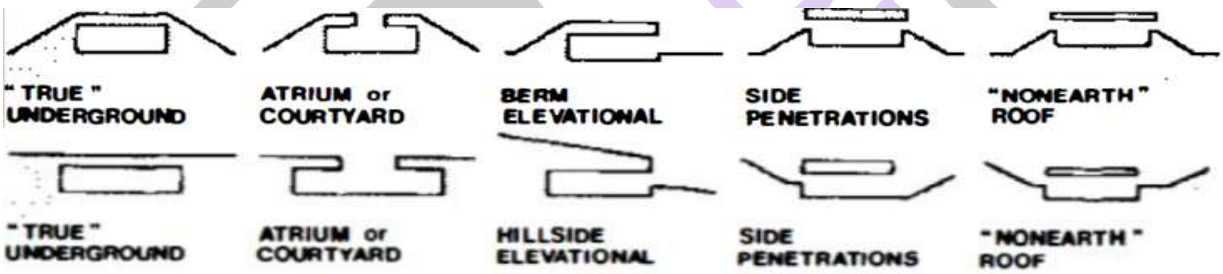

Figure 1: Classification of different underground building concepts

Fully underground spaces

These spaces have little or no contact with the above world. They can be either just below the surface or deep under the earth. Generally, only the entrance is aboveground. In principal, fully underground spaces have a mechanical supply of light and air.

Submerged spaces

Submerged spaces are those lying just under the surface of the ground. They extend deep into the ground but they always have direct contact with the above ground world and with natural light.

Earth-covered spaces

An earth-covered building is not underground, but rather at grade, with a surface laid over it.This building type is free of the technical disadvantages of underground building, while enjoying its spatial advantages. Daylight can penetrate normally and views are usually unimpaired. The elevated ground level can be laid out as a park, landscape, or urban environment. In majority of the cases, these buildings can be constructed in the traditional manner. Only the roofing and cladding of one or more facades is essentially different.

Underground buildings are generally connected in one way or another with aboveground buildings, may it be for the entrance to the building or a larger part of the building that is situated aboveground, in the latter the underground part is generally referred to as its cellars or basement.

EARTHQUAKES FORCES:

Earthquakes, one of the most powerful natural forces are the shaking of the earth caused by pieces of the crust of the Earth that suddenly shift. The crust, the thin outer layer, is mostly cold and brittle rock compared to the hot rock deeper inside.

This crust is full of large and small cracks called faults. Although these faults can be hundreds of miles long, usually you cannot see the cracks because they are buried deep underground and because the pieces of crust are compressed together very tightly. The powerful forces that compress these crustal pieces also cause them to move very slowly. When two pieces that are next to each other get pushed in different directions, they will stick together for a long time (many years), but eventually the forces pushing on them will force them to break apart and move. This sudden shift in the rock shakes all of the rock around it. These vibrations, called seismic waves, travel outward in all directions and are called an earthquake. The underground location where the rock first broke apart or shifted is called the focus of the earthquake.

EARTHQUAKE EFFECTS ON UNDERGROUND STRUCTURES:
Earthquake effects on underground structures can be grouped into two categories:

1) ground shaking and
2) ground failure such as fault displacement, liquefaction and slope instability. Ground shaking refers to deformation of the ground produced by seismic waves propagating through the earth's crust.

The major factors influencing shaking damage include:

1) the shape, depth, and dimensions of the structure
2) the surrounding soil or rock properties
3) structure properties
4) the severity of the ground shake.

II. LITERATURE REVIEW:

C. Navarro (1992) In this paper a large structure of reinforced concrete of box shape and totally embedded in soil, is analyzed. The dynamic pressure acting on roof, wall and floor due to body and surface waves are considered in the analysis. A set of seismic load combination for the different polarization planes of the seismic waves are proposed.

VikasPratab Singh (1995) Reviewed that dynamic response of a structure resting on soft soils may substantially differ in amplitude and frequency from the response of an identical structure supported on a rock or a very stiff soil. The interaction phenomenon between soil and the structure is principally affected by the mechanism of energy exchanged between them.

D. Inglis, G. Macleod, E. Naesgaard, M. Zergoun (1996)
This paper summarizes the geotechnical aspects considered in the analysis and design of reinforced concrete basement wall with up to four underground levels. The structure is founded on firm glacial soils however the walls have to retain soft/loose and potentially liquefiable soils which could exert large seismic earth pressure on the structure. Ground improvement and a novel expanded polystyrene buffer layer were incorporated in the design in order to reduce lateral seismic loads on the underground structure. The analysis indicated an approximately 50% reduction in seismic earth pressure loads by use of the expanded polystyrene buffer layer.

Hamid Reza Tabatabaiefer (1998) Recognized that the soil strata can indeed affect the response of structures, especially founded on relatively flexible soils. In the study of soil-structure interaction problem apart from the design parameters of the structure and type of ground excitation is taken, the dynamic properties of soil also play important role in obtaining seismic response.

B.K.Maheshwari (2001) Describes the influence of soil-structure interaction and is compared with the results obtained when the structure is assumed to be fixed at the base, it is observed that the fundamental natural frequencies increase and base shears decrease with the increase of soil stiffness and this change is found more in soft soils.

Sang-Hyeok Nam, Ha-Won Song, Keun-JooByun, Koichi Maekawa (2006) Since underground reinforced concrete (RC) structures interact with the surrounding soil medium, the behavior of the interfacial zone between the RC structure and the surrounding medium of the underground RC structure should be considered for accurate seismic analysis. In this paper, an averaged constitutive model of concrete and reinforcing bars for the RC structure and the path-dependent Ohsaki'smodel for the soil are applied, and an elasto-plastic interface model which considers the thickness of the interface is proposed for seismic analysis of underground RC structures. A finite element analysis program is developed and verified by predicting both static and dynamic behaviors of underground RC structures. Then, the effects of the interface on the behavior of underground RC structures are analyzed. The effect of stiffness of the RC structure due to different reinforcement ratios of underground RC box structures to the behavior of the structures is also analyzed. Finally, failure mechanisms of underground RC structure under seismic action are simulated through seismic analysis of an underground RC station structure.

S. S. Basarkar, Manish Kumar, B.G. Mohapatro, P.R. Mutgi (2011) In this context, Top-Down construction has been increasingly used in urban areas, particularly for high rise buildings with basements so that the sub-structure and super-structure works can be executed concurrently.This paper presents details of Top-Down construction technology. Important component of this technique is the Diaphragm wall, which is a specialized slender retaining wall constructed from the ground. Construction intricacies and methodology of execution of such wall also form part of this paper. Two case summaries are reported on Top-down construction executed by principle authors' firm. One such site comprised multi-level car parking facility in a crowded area of Delhi, while other formed a part of underground metro station at Kolkata. The paper concludes with words of indispensability of such technology for early commissioning of the structures.

G. Saad, F. Saddik& S. Najjar (2012) This paper studies the seismic behaviour of reinforced concrete buildings with multiple underground stories. It seeks to provide recommendations on the number or percentage of underground stories to be accounted for in the analysis of reinforced concrete shear wall buildings. A base-case where the buildings are modeled with a fixed condition at ground level is adopted, and then the number of basements is incrementally increased to investigate changes in performance. The Beirut local site conditions are used for the analysis. The base shear, inter-story shears and moments are evaluated in order to quantify the effects of soil structure interaction on the design process.

VasanthAcharya, Akshaya, Shivananda S.M, H L Suresh (2014) The paper evaluates the performance of framed buildings under future expected earthquakes, a non-linear static pushover analysis has been conducted on a typical multi-storey car parking structure. To achieve this objective, a 3D framed multi storey car parking structure (G+3) is modeled in SAP 2000 in which the structure is open in all stories with rigid floors. The effect of strength irregularities in the present multi-storey car parking structure of R/C frames on the seismic performance using nonlinear static push-over analysis based on computational models is done. From output non-linear analysis, we compare the Base shear and Displacement occurs in different strength irregularities for the different load combinations in seismic zone IV.

Chaitanya Patel, Noopur Shah (2016) This paper studies the seismic behavior of reinforced concrete buildings with multiple underground stories.While current researches mainly aims at understanding the effects of variation in soil subgrade modulus, this study has the ultimate goal of finding appropriate recommendations concerning the inclusion of underground stories in the model for seismic analysis. To achieve this objective, the methodology involves the computer modelling by two alternate approaches, namely, building frame with fixed supports, building frame with supports accounting for soil-flexibility using STAAD.Pro. A comparison of the displacements of the frame and time period of the whole structure is done.

III CONCLUSION:

The underground structures do not have their own mode of vibration and natural period hence the deformation of underground structures is governed by relative displacements of the surrounding ground during earthquakes. The effects of material non homogeneity, soil-structure interaction, stratification of soil, ground water table fluctuation, and inherent properties of soil strata needs due consideration in dynamic behavior of underground structures.To study the earthquake effects a detailed seismic analysis by considering the type of soil and site conditions should be carried out.Underground structures should be designed for imposed seismic ground deformations rather than inertial forces. Longitudinal seismic analysis should be carried out along with transversal analysis, also dynamic analysis should be carried out for evaluating stresses and strains at critical points.To model the soil-structure interaction effects, the dynamic time-history analysis using 3D finite element modelling should be carried out.

REFERENCES:

[1] IS:1893(Part-1):2002,Criteria for earth quake resistant design of structure.
[2] IS 1893, Indian Standard Criteria for Earthquake Resistant Design ofStructures. Part 5 (fourth revision), 1984.
[3] Chopra, A. K., "Dynamics of Structures", Earthquake Engineering Research Institute, Berkeley, California's
[4] NithyaChandran J, AbhilashRajan, Soni Syed, "Seismic Analysis of Building with Underground Stories Considering SoilStructure Interaction." International Journal of Emerging Technology and Advanced Engineering Volume 4, Issue 11,November 2014
[5] G. Saad, F. Saddik& S. Najjar, "Impact of Soil Structure Interaction on the Seismic Design of Reinforced Concrete Buildingswith Underground Stories." American University of Beirut, Lebanon 2012
[6] Tuladhar, R., Maki, T., Mutsuyoshi, H. "Cyclic behavior of laterally loaded concrete piles embedded into cohesive soil,Earthquake Engineering & Structural Dynamics" Vol. 37 (1), pp. 43-59,2008
[7] Jinu Mary Mathew, Cinitha A, Umesha P K, Nagesh R Iyer and Eapen Sakaria3, "Seismic Response of Rc Building byConsidering Soil Structure Interaction." ISSN 2319-6009, Vol. 3, IJSCER, 2014
[8] Shiji P.V, Suresh S., Glory Joseph, "Effect of Soil Structure Interaction in Seismic Loads of Framed Structure." International Journal of Scientific & Engineering Research, Volume 4, Issue 5, May-2013
[9] W.V. Zinn, Economic design of deep basements, *Civ. Engnr. Public Works Rev*., 68, March, 1968, 275-280.
[10] M. Puller, *Deep excavations – a practical manual* (2nd Edition, Thomas Telford Ltd., London, 2003).
[11] G.Y. Fenoux, Le RelisationFouilles en Site Urbain. *Travaux,* Parts 437 and 438, Aug-Sept., 1971, 18-37.
[12] S.P. Marchand, A deep basement in Aldersgatestreet, London, Part2: Construction, *Proc. Instn Civ. Engnrs.*, 1993, 67-76.
[13] S.P. Marchand, A deep basement in Aldersgatestreet, London, Part2: Construction, *Proc. Instn Civ. Engnrs.*, 1993, 67-76.
[14] R. Fernie, Movement and deep basement provision at Kinghtsbridge Crown Court, Harrods, London, *Conf. Response of Buildings to Excavation-induced Ground Movements*, CIRIA , July, 2001.
[15] J. Kenwright, R.A. Dickson, and R. Fernie, Structural movement and ground settlement control for a deep excavation within a historic building, *Proc. DFI Conference 2000*, Eaglewood Cliffs, New Jersey, 2000.

[16] M.S. Fletcher, The 'Down' of Top-down, *Civil Engnrs*, 58, 1988, 58-61.
[17] J.Y.H. Lui, and P.K.F. Yau, The performance of deep basement for the dragon centre, *Proc. of Seminar on Instrumentation in Geotechnical Engineering*, Hong Kong Institution of Engineers, 1995, 813 -201.
[18] A. Mitchell, C. Izumi, B. Bell, and S. Brunton, Semi Top-Down construction method for Singapore MRT, NEL, *Proc. Int. Conf. on Tunnels and Underground Structures*, Singapore, Balkema, Rotterdam, 2000.
[19] M. Kumar, Deep support systems using diaphragm walls and contiguous piles, *Proc. National Seminar on Deep Excavations in Urban Environment*- Mumbai, India, 2008.
[20] Shakib H. (2004), Evaluation of Dynamic Eccentricity by Considering Soil–Structure Interaction: a Proposal forSeismic Design Codes, *Soil Dynamics and Earthquake Engineering,* **24**, pp. 369-378.
[21] Tabatabaiefar R. and A. Massumi (2010), A Simplified Method to Determine Seismic Responses of ReinforcedConcrete Moment Resisting Building Frames Under Influence of Soil–Structure Interaction, *Soil Dynamicsand Earthquake Engineering*, **30**, pp. 1259-1267.